Effects of linear versus large footprint sampling on measured radiative heating rate and cloud water content profiles: CALIOP vs CERES scale

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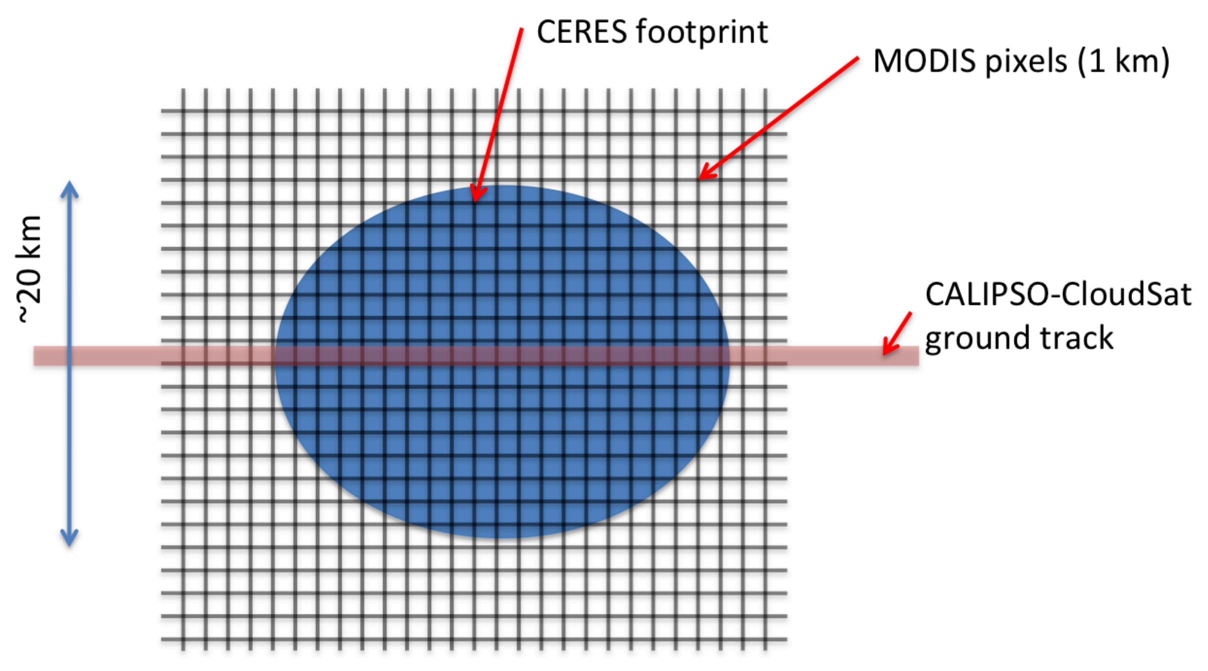
C3M: A-Train Integrated CALIPSO, CloudSat, CERES, and MODIS Merged Product

- Uses instrument synergy to improve estimates of cloud and radiative variables.
- Based on existing CERES products, cloud and aerosol data from CALIPSO and CloudSat added.
- Radiative fluxes computed.

C3M: A-Train Integrated CALIPSO, CloudSat, CERES, and MODIS Merged Product



Resolution:

CERES	~20 km
MODIS	≤1 km
CloudSat	1.5 km
CALIOP	100 m

MERRA: 0.5 x 0.625°

Analysis Method

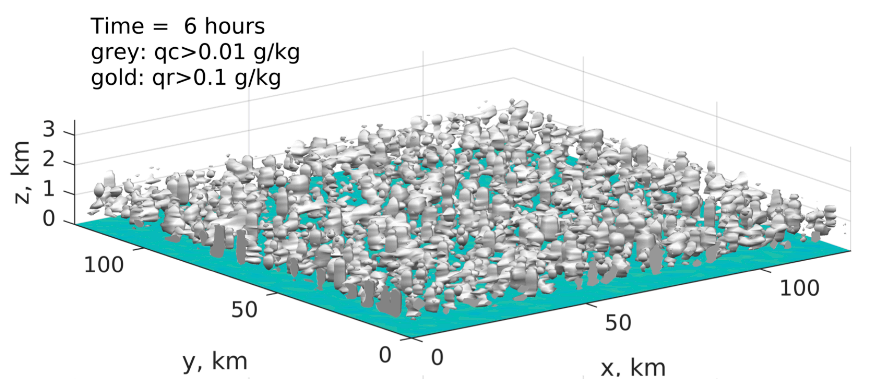
- Obtain cloud model output for various cloud types.
- Average cloud water mixing ratio and atmospheric heating rate profiles over CERES footprint scale areas.
- Extract data along “CALIOP” slices through footprint and average.
- Statistically compare CERES and “CALIOP” profiles.

Case 1: Weakly forced trade cumulus clouds

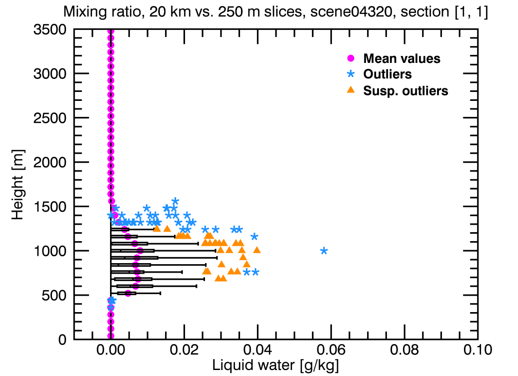
- S6 specifications for CGILS intercomparison.
- Covers cloud formation through mesoscale aggregation.
- 128 km x 128 km domain with 250 m grid spacing.
- Break into 36 areas of 20 km x 20 km.

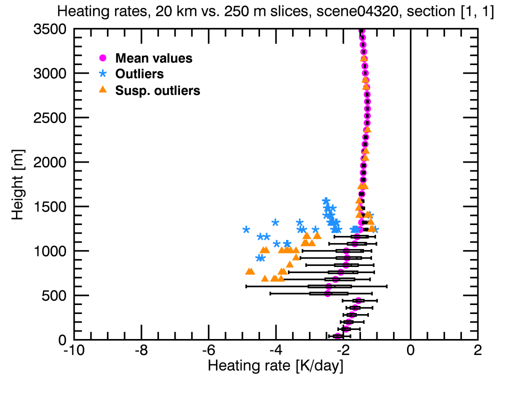
(From Bretherton and Blossey)

Case 1, t = 6 hours



Mixing ratio





Heating rate

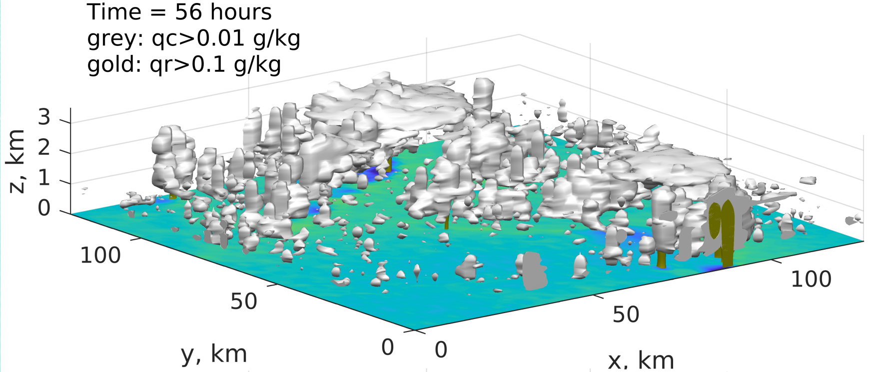
Appears uniform.

Small LWMR and heating rate values.

LWMR upper quartile 2-3x median.

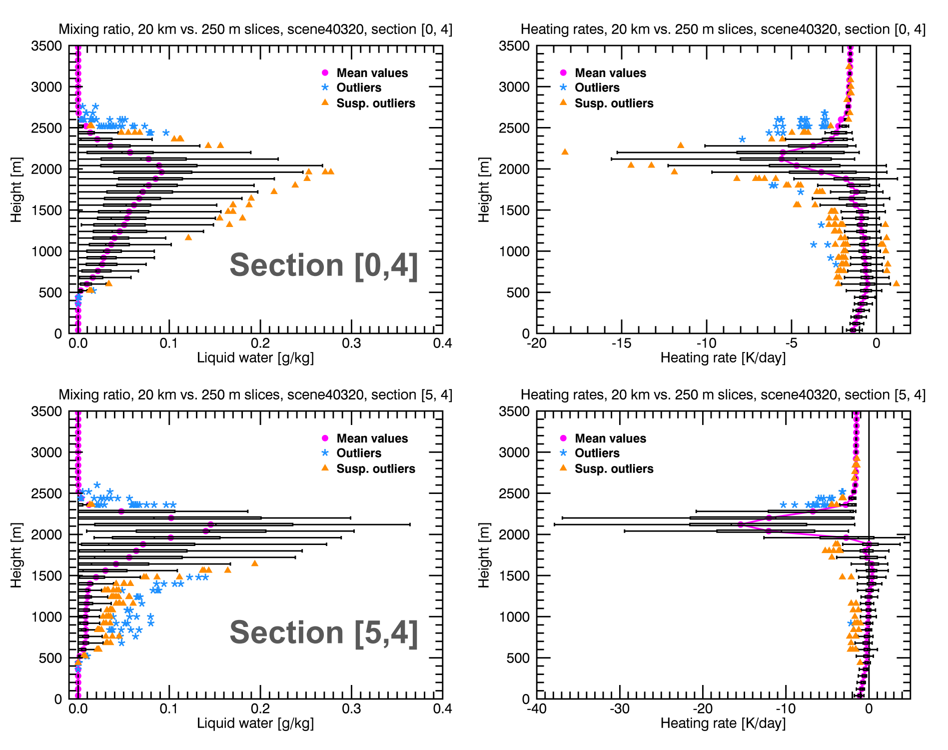
Heating rate upper quartile 1.5x median.

Case 1, t = 56 hours



Mixing ratio

Heating rate



Appears highly variable.

Larger values (10x).

[0,4] LWMR & HR quartiles ~median.

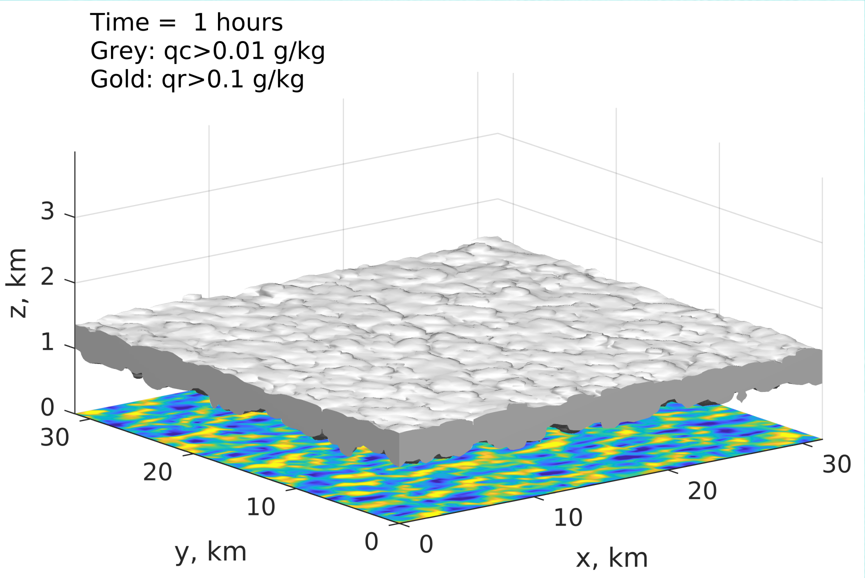
[5,4] quartiles several x median.

Case 2: Cold air outbreak

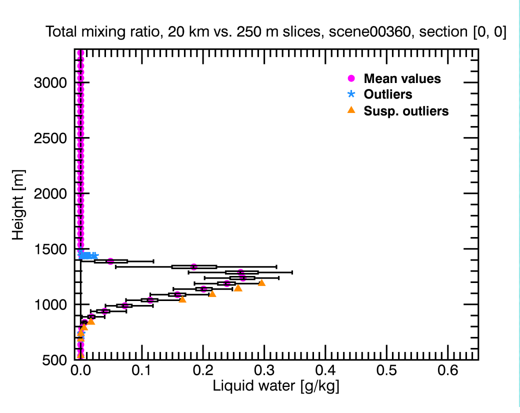
- CONSTRAIN simulation.
- Boundary layer deepens due to strong surface forcing.
- Covers progression from shallow overcast to deeper and broken.
- 32 km x 32 km domain with 250 m grid spacing.
- Analyzed 20 km x 20 km overlapping regions.

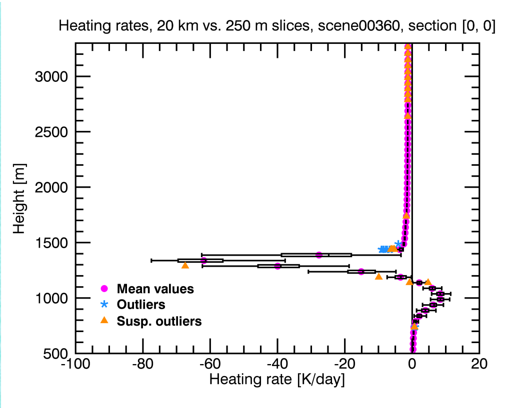
(From Rachel Atlas)

Case 2, t = 1 hour



Mixing ratio

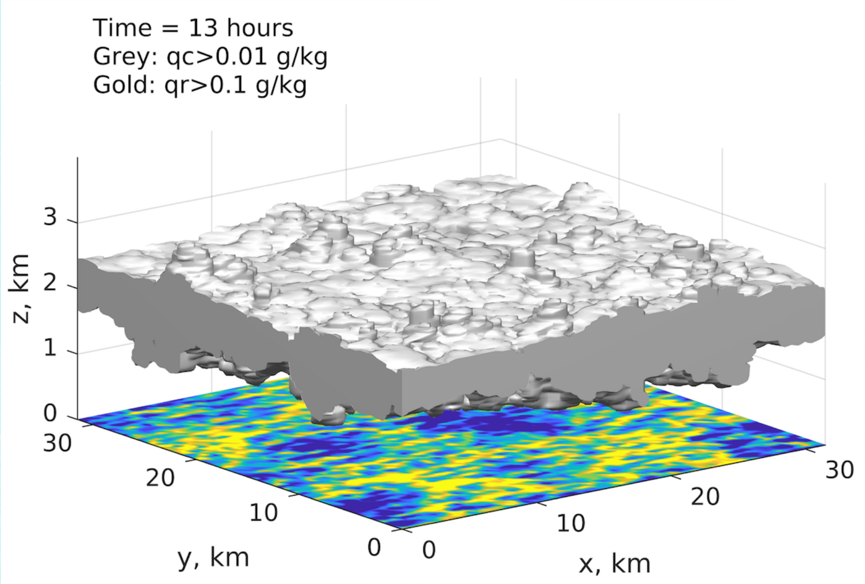




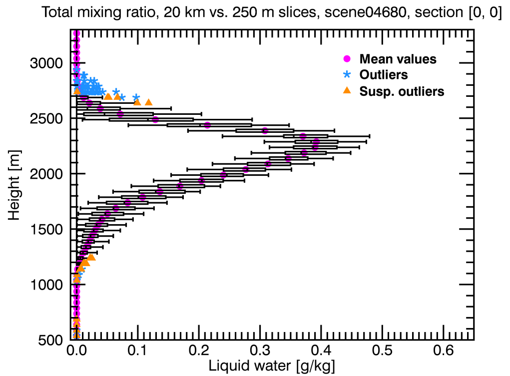
Heating rate

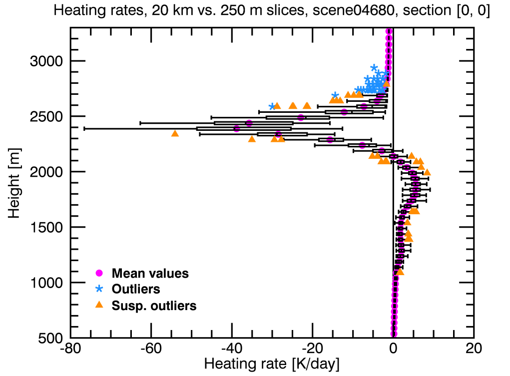
Appears uniform.
Significant LWMRs and heating rates.
LWMR and HR values relatively constant.
Upper quartiles less than 0.5x medians.

Case 2, t = 13 hours



Mixing ratio





Heating rate

Appears moderately uniform.

Highest LWMR values.

LWMR and HR values relatively constant except at cloud top and base.

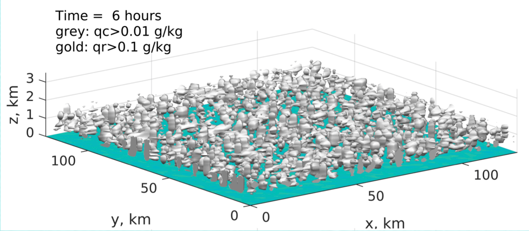
Averaging effects

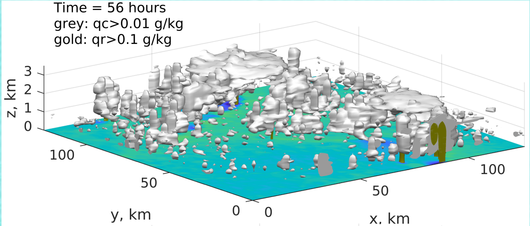
Given results, will differences average out?

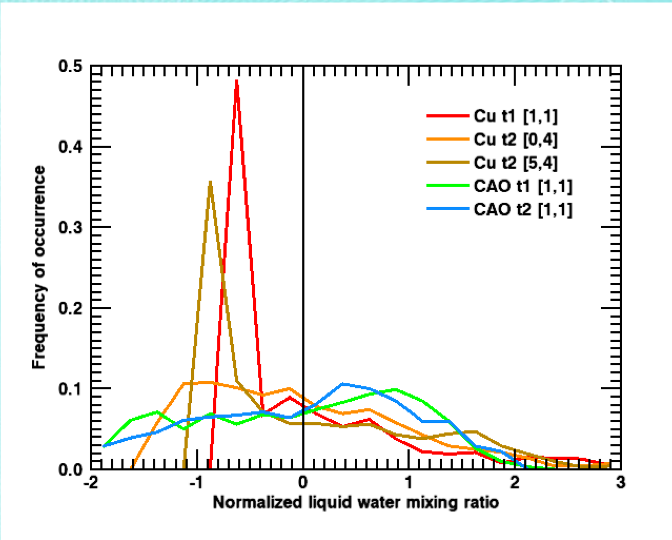
Compute probability distribution functions using data for lines at multiple levels within clouds.

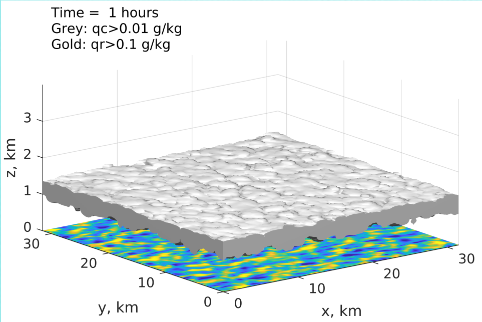
Assume mean is “representative.”

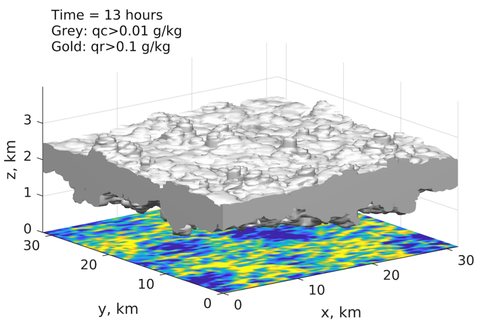
Liquid water mixing ratio PDFs









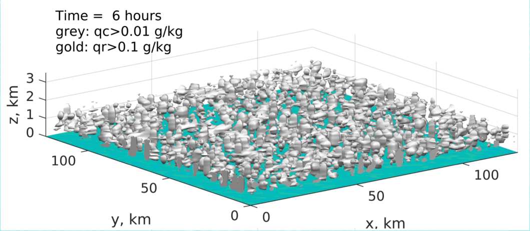


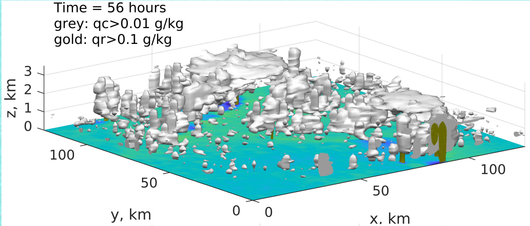
Peaked distributions for "uniform" cases (Cu).

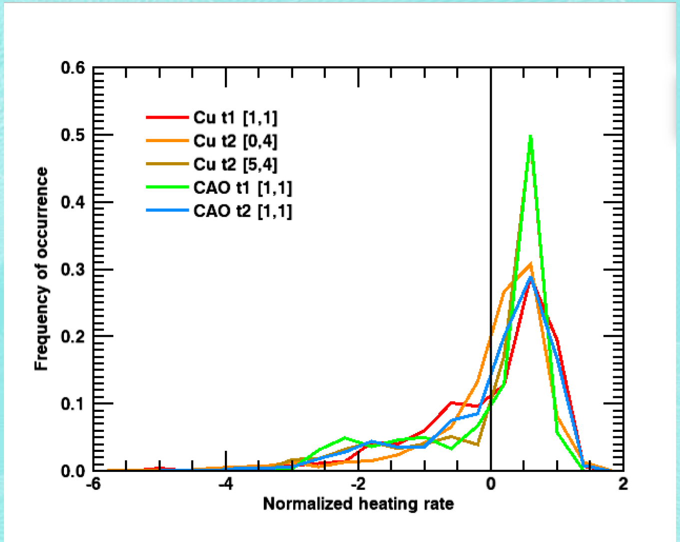
→ Sample generally low, but large values possible.

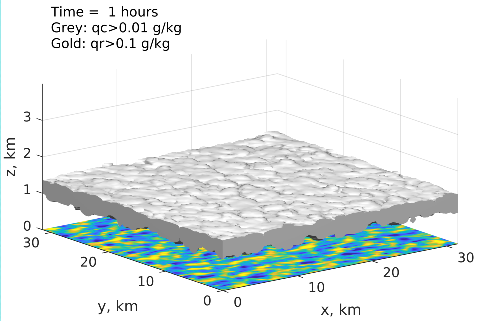
Flat distribution for least variable cases (CAO).

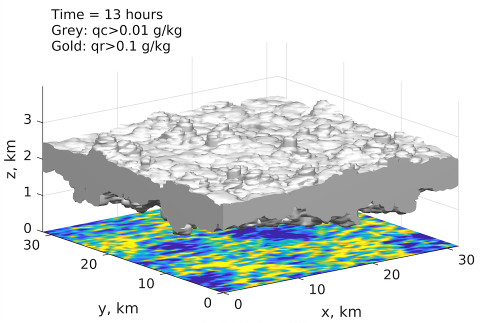
Heating rate PDFs











"Anvil" and uniform Sc most peaked.

All PDFs skewed negative, sample value likely high.

Most values fall within a 1σ width, but low values possible.

Conclusions

- Magnitude of liquid water mixing ratio or heating rate along a line at one height can be off by several times the median.
- Variability depends on spatial uniformity.
- LW mixing ratio distributions highly peaked for Cu cases, with long tails.
- LW mixing ratio distributions flat for COA cases → should average out over many samples.
- Heating rate distributions all skewed negative, but with large peak areas → high likelihood of sampling close to median.

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Q: Learn more using bootstrap sampling?